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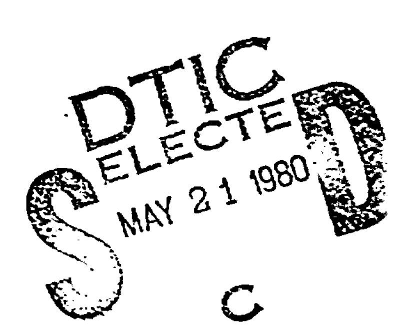
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ABSTRACT

In acquiring a skill by means of instruction and experience, the student normally passes through five developmental stages which we designate novice, competence, proficiency, expertise and mastery. We argue, based on analysis of careful descriptions of skill acquisition, that as the student becomes skilled he depends less on abstract principles and more on concrete experience. We systematize and illustrate the progressive changes in a performer's ways of seeing his task environment. We conclude that any skill-training procedure must be based on some model of skill acquisition, so that it can address, at each stage of training, the appropriate issues involved in facilitating advancement.

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I. INTRODUCTION

Anyone who wishes to acquire a new skill is immediately faced with two options. He can, like a baby, pick it up by imitation and floundering trial-and-error, or he can seek the aid of an instructor or instructional manual. The latter approach is far more efficient, and in the case of dangerous activities, such as aircraft piloting, essential. We shall describe below our model of the normal directed skill acquisition process and illustrate our rather abstract characterization with examples from foreign language acquisition, chess learning, and flight instruction.

Our method consists in analyzing and systematizing descriptions of changes in the perception of the task environment reported by performers in the course of acquiring complex skills. Sudnow [1], trained as an ethnographer, has described in great detail the changing stages in the meaning and temporal organization of sound patterns in the course of his acquisition of the ability to improvise jazz. We have adapted these findings to the stages in the acquisition of facility in speaking a second language, since this form of skill acquisition is likely to be more familiar to the reader. The psychologist De Groot [2] has reported on the changing way the chess array is perceived by beginners and experienced players. In our illustrations of our

model with respect to flying, we have relied on pilot interviews and instructional manuals.

This descriptive data, while precise and replicable, might seem to lack the objectivity and quantifiability produced by controlled laboratory experiments. However, there is a long tradition in psychology and philosophy of suspicion of the significance of experimental results produced by restricting experiments to precisely controlled but highly artificial situations. Gestaltists such as Köhler [3] and phenomenologists such as Merleau-Ponty [4] have argued that research programs such as behaviorism and cognitivism which attempt to eliminate the everyday perceptual familiarity of the experimental situation reach their conclusion that perception and skills etc. are based on the lawlike combination of elements precisely because they have eliminated the contextual significance, based on past experience, which makes other forms of response possible. Moreover, recent research on judges setting bail and pronouncing sentences [5] has shown that even the simple fact of the subject knowing that he is taking part in a psychological experiment produces a marked change in behavior. In laboratory settings, actual judges operated according to the recommended rules of procedure found in various published guidelines. Unobstrusively observed in the naturalistic courtroom setting, however, these same judges behaved quite differently, relying heavily on the recommendations of attorneys and probation officers. Experience seems to have taught the judges to trust experts, rather than apply rules. Concerning scientific laboratory observation as a means of studying real-world behavior, Konečni and Ebbesen conclude

"... erroneous information obtained by scientific methods (and therefore having an aura of truth) is more harmful than no information at all ..." [6].

Despite the intrinsic tendency of controlled experiments to produce behavior which masks the changes in skilled performance which takes place over long periods of experience, some indications of these changes have shown up even under these adverse conditions. Schneider and Shiffrin have distinguished controlled processing--a temporary activation of a sequence of elements that can be set up quickly and easily but requires attention is capacity limited (usually serial in nature) and is controlled by the subject--from automatic processing--a learned sequence that is initiated by appropriate inputs and then proceeds automatically without stressing the capacity limitations of the system, and without necessarily demanding attention. They conclude, based on experimental evidence involving very simple detection, search and attention tasks, "In novel situations or in situations requiring moment-to-moment decisions, controlled processing may be adopted and used to perform accurately, though slowly. Then, as the situations become familiar, always requiring the same sequence of processing operations, automatic processing will develop, attention demands will be eased, other controlled operations can be carried out in parallel with the automatic processing, and performance will improve" [7].

One further interesting recent result of laboratory research is the unexpected discovery that when the same task can be described as a sequence of formal operations, and alternatively as a familiar

concrete problem, the subject's behavior dramatically improves when he is presented the task in a concrete everyday form. An abstract logical task involving a conditional rule was studied extensively by Wason in 1966. Here is one example of the problem Wason studied and his results:

> "You are presented with four cards showing, respectively, 'A', 'D', '4', '7', and you know from previous experience that every card, of which these are a subset, has a letter on one side and a number on the other side. You are then given this rule about the four cards in front of you: 'If a card has a vowel on one side, then it has an even number on the other side.'
>
> Next you are told: 'Your task is to say which of the cards you need to turn over in order to find out whether the rule is true or false.'
>
> The most frequent answers are 'A and 4' and 'only A'. They are both wrong. The right answer is 'A and 7' because if these two stimuli were to occur on the same card, then the rule would be false but otherwise it would be true. Very few highly intelligent S's get the answer right spontaneously; some take a considerable time to grasp it; a small minority even dispute its correctness, or at least remain puzzled by it ..." [8].

In 1972, it was demonstrated that the subject's performance dramatically improves if the selection task relates more closely to his experience.

> "The subjects were instructed to imagine that they were postal workers engaged in sorting letters on a conveying belt; their task was to determine whether the following rule had been violated: 'If a letter is sealed, then it has a 5d stamp on it.' The material consisted of four envelopes arranged as follows: the back of a sealed envelope (p); the back of an unsealed envelope ($\bar{p}$); the front of an envelope with a 5d stamp on it (q); the front of an envelope with a 4d stamp on it ($\bar{q}$). The instructions were to select only those envelopes which definitely needed to be turned over to find out whether, or not, they violated the rule. There were twenty-four subjects and they performed the task under both this 'concrete' condition, and under an 'abstract' control condition in which arbitrary symbols were associated in the usual way. Under the 'concrete' condition twenty-two subjects were correct, and under the control, 'abstract' condition seven were correct" [9].

This striking dependence on *everyday, concrete, experience* in problem solving seems an anomaly from the point of view of the information processing model of mental activity whose basic assumption is that all cognitive processes are produced by *formal* manipulation of independent bits of information abstracted from the problem domain. Various attempts have been made to deal with the above experimental results. Whether it is the concrete terms, or the realistic relation between the terms, or a combination, that facilitates performance is in disagreement, as is the explanatory nature of various proposed information processing models. One fact seems clear, however, to the pioneering investigators, Johnson-Laird and Wason:

> "The subjects' ordinary experience is relevant to problem solving performance, and our 'realistic guise' touches this experience" [10].

Our approach is to take the reliance on everyday familiarity in problem solving not as an anomaly, but as a pervasive and essential feature of human intelligent behavior. Therefore, in the account of skill acquisition which follows, concrete experience plays a paramount role. Rather than adopting the currently accepted Piagetian view that proficiency increases as one moves from the concrete to the abstract, we argue that skill in its minimal form is produced by following abstract formal rules, but that only experience with concrete cases can account for higher levels of performance. Furthermore, if concrete experience is necessary and sufficient for proficiency, then, as we indicate in

Sections III-IV, one has the option of dispensing with any formal information processing explanation of skill acquisition and can offer neurological speculations as alternative explanations of skillful behavior.

A detailed understanding of the stages through which skillful performance develops is essential if one is to design training programs and training materials to facilitate the acquisition of high-order skills. In any such endeavor, it is essential to identify at each stage what capacities the performer has acquired and which more sophisticated capacity he is then in a position to attain.

The five-stage process we present here is an elaboration and systematization of the three stages identified in [11] and the additional stage introduced in [12]. The typography worked out in this paper forms the basis in a companion paper [13] of a critical evaluation of a recent proposal [14] for the design of procedures for training aircrew emergency decision skills.

II. STAGE 1: NOVICE

Normally, the instruction process begins by decomposing the task environment into context-free *features* which the beginner can recognize without benefit of experience. We will call such features, which can be recognized without experience of particular situations in the instructional domain, *non-situational*. The beginner is then given *rules* for determining an action on the basis of these features. To improve, the novice needs monitoring, either by self-observation or instructional feedback, so as to bring his behavior more and more completely into conformity with the rule.

A student, acquiring a second language, would be classified as novice when he had learned the phonetic rules for producing and recognizing what seemed to him meaningless noises which got specific results when produced on specific occasions. The novice chess player sees pieces as context-free elements and knows a few simple rules such as the rule for computing the material value of a position by adding up a material value he has learned to assign to each type of piece. The novice pilot knows how to read cockpit instruments and how to manipulate the controls in response to such features as instrument readings and context-free visual cues such as the angular displacement of the horizon.

III. STAGE 2: COMPETENCE

Competence comes only after considerable experience actually coping with real situations in which the student notes or an instructor points out recurrent meaningful component patterns. These *situational* components, in terms of which a competent student understands his environment, are no longer the context-free features used by the novice. We will call these recurrent patterns *aspects*. Aspect recognition cannot be produced by calling attention to recurrent sets of features, but only by singling out perspicuous examples. The brain-state correlated with the example being pointed out is organized and stored in such a way as to provide a basis for future recognition of similar aspects. While there is no in-principle argument proving that this organizing and storing process could not take the form of abstract rules operating over context-free features, there is not a shred of experimental evidence supporting this contention. It seems more plausible, as argued in Reference [15], that what is stored is simply a brain-state record in no way decomposed into "bits of information." The instructor can formulate principles dictating actions in terms of these aspects. We will call such principles, which presuppose experience-based meaningful elements, *guidelines*. The guidelines treat all aspects as equally important and are formulated so as to integrate as many aspects as possible.

A language learner has achieved competence when he no longer hears and produces meaningless streams of sound,

but rather perceives meaningful phrases which, when used on appropriate occasions, produce effects by virtue of these meanings. Some typical chess aspects are "weakness on the king's side," "over-extended," and "unbalanced pawn structure," and the competent player knows how to bring about and diminish these aspects, and which are to be sought and which avoided. The competent pilot can recognize such aspects as "high in the landing approach envelope," "verging on stall conditions," and "dangerous crab angle," and knows guidelines for correcting such conditions.

IV. STAGE 3: PROFICIENCY

Increased practice exposes the performer to a wide variety of typical whole situations. Each whole situation, for the first time, has a meaning which is its relevance to the achievement of a long-term goal. Aspects now appear to be more or less important (salient) depending upon their relevance to this goal. The brain-state correlated with the performer's experiencing a whole situation from a particular perspective is organized and stored in such a way as to provide a basis for future recognition of similar situations viewed from similar perspectives. A specific objective situation, confronted at two different times, each time from a different perspective, would be treated as two different situations.* Given a set of aspects and their saliences, the performer uses a memorized principle which we call a *maxim* to determine the appropriate action.

The language learner finally becomes able to combine the phrases he uses into whole sentences, with subordinate clauses, which enable him to describe whole situations, and to use language to request, demand, order etc. whole states of affairs. The chess player now sees aspects such as "unbalanced pawn structure" as either irrelevant or crucial to some overall strategic goal, such as "attack" or "play for a positional end-game advantage." Given his particular long-range goal, he uses maxims to decide on moves which change the crucial aspects of his position and that of his opponent's to his

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*For the first time, borderline situations can occur in which the appropriate perspective is in question. This phenomenon is dealt with in detail in Reference [13].

advantage. The proficient pilot, intent, for example, on making a safe landing, sees his position in the landing envelope and his crab angle as salient while ignoring the terrain beyond the far end of the runway. He maneuvers down following maxims which dictate actions which correct deviations from desired conditions. If the deviations become too large he may adopt a different perspective in view of a possible "go around," in terms of which the runway length and terrain beyond its far end become crucial.

V. STAGE 4: EXPERTISE

The expert performer in a particular task environment has reached the final stage in the step-wise improvement of mental processing which we have been following. Up to this stage, the performer needed some sort of analytical principle (rule, guideline, maxim) to connect his grasp of the general situation to a specific action. Now his repertoire of experienced situations is so vast that normally each specific situation immediately dictates an *intuitively* appropriate action. This intuition is possible because each type of situation, as distinquished in Section IV, now has associated with it a specific response.

After a great deal of experience actually using a language in everyday situations, the language learner discovers that without his consciously using any rules, situations simply elicit from him appropriate linguistic responses. By virtue of previous experience with actual board positions or the involved study of such positions, an appropriate move or tactical idea presents itself to the chess expert each time he sees a meaningful chess array. The expert pilot, having finally reached this non-analytical stage of performance, responds intuitively and appropriately to his current situation. Pilots report that at this stage, rather than being aware that they are flying an airplane, they have the experience that they are flying. The magnitude and importance of this change from analytic thought to intuitive response is evident to any expert

pilot who has had the experience of suddenly reflecting upon what he is doing, with an accompanying degradation of his performance and the disconcerting realization that rather than simply flying, he is controlling a complicated mechanism.

VI. STAGE 5: MASTERY

Although, according to our model, there is no higher level of mental capacity than expertise, the expert is capable of experiencing moments of intense absorption in his work, during which his performance transcends even its usual high level. We discuss this stage in Reference [12] where we note that this masterful performance only takes place when the expert, who no longer needs principles, can cease to pay conscious attention to his performance and can let all the mental energy previously used in monitoring his performance go into producing almost instantaneously the appropriate perspective and its associated action.

VII. SUMMARY AND TRAINING IMPLICATIONS

The above developmental description can be seen systematically as the result of the successive transformation of four mental functions. Each of the four mental functions has a primitive and a sophisticated form and the functions are so ordered that attaining the sophisticated form of each presupposes the prior attainment of the sophisticated form of all those lower numbered in the ordering. Each row in Table 1 represents a form of mental function. In column 1 all four forms are in their primitive state, and in each subsequent column, one additional form has been transformed into its sophisticated state. As a result, there are five columns, and each corresponds to one of our five stages of mental activity involved in skill acquisition.

TABLE 1

Skill Level / Mental Function	NOVICE	COMPETENT	PROFICIENT	EXPERT	MASTER
Recollection	Non-situational	Situational	Situational	Situational	Situational
Recognition	Decomposed	Decomposed	Holistic	Holistic	Holistic
Decision	Analytical	Analytical	Analytical	Intuitive	Intuitive
Awareness	Monitoring	Monitoring	Monitoring	Monitoring	Absorbed

In reading the table, one should recall the following. The development depicted in row 1 first becomes situational when experience-based similarity recognition is achieved. This first occurs when the performer is able to recognize aspects. The development in row 2 first becomes holistic when the performer perceives similarity in terms of whole situations. This change is accompanied by the recognition of salience. In row 3, the performer refines whole situations to the point that unique decisions intuitively accompany situation recognition without need of conscious calculation. In row 4, the analytical mind, relieved of its monitoring role in producing and evaluating performance, is quieted so that the performer can become completely absorbed in his performance.

The training implications of this taxonomy are obvious. The designer of training aids and courses must at all times be aware of the developmental stage of the student, so as to facilitate the trainee's advancement to the next stage, and to avoid the temptation to introduce intricate and sophisticated aids which, although they might improve performance at a particular level, would impede advancement to a higher stage, or even encourage regression to a lower one.

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